Neogene Pectinidae of the Northern Pacific

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(1 Text figure)

INTRODUCTION

It is well known that the Neogene Pectinidae is one of the most important groups of mollusks for age determination and correlation of Neogene strata because of their rather short geological range and also because they are the largest group of fossil marine mollusks. The long duration from spawning through the pelagic and sessile stages to the free swimming stage favors wide dispersal, colonization of new habitats and, consequently, speciation. Also, as the pectinid shells are usually rather well preserved even when the majority of the associated shells are represented as molds or casts, their collection and identification is facilitated. Therefore, they are good tools for interregional correlation.

Among the Neogene pectinids of the Northern Pacific region *Patinopecten, Mizuhopecten, Yabepecten, Swiftopecten, Fortipecten* and *Chlamys cosibensis* (Yokoyama) are considered to be significant for interregional correlation between Eastern Asia and North America because they are known from the Japanese Islands, Sakhalin, Kamchatka, Alaska and the West Coast of North America. Also, the genus *Amussiopecten* is considered to be one of the most interesting and significant pectinids particularly from the viewpoint of its world wide distribution.

In the present article remarks on the above mentioned Neogene pectinids of the Northern Pacific are given and paleontological significances are also discussed.

NOTES ON PECTINIDS OF THE NORTHERN PACIFIC

1) *Patinopecten* and *Mizuhopecten*

The genus *Patinopecten* is one of the most interesting Cenozoic pectinids of the eastern North Pacific, because it is abundant in species, shows a wide range of morphological characters and has a rather restricted geological range.

Patinopecten was established by Dall (1898) as a section of the genus *Pecten* based upon *Pecten caurinus* Gould, a common Recent scallop of the eastern North Pacific. Thenceforth, *Patinopecten* has frequently been recorded from the Recent seas of the Northern Pacific and from the Tertiary and Quaternary deposits of western North America, the Japanese Islands, Sakhalin, and Kamchatka, but not from elsewhere. From a study of the so-called *Patinopecten* of Japan the writer (Masuda, 1963) pointed out that all of the Japanese fossil and Recent species of the so-called *Patinopecten* differs from the true *Patinopecten* of North America and he proposed the new genus *Mizuhopecten* for most of the species of the so-called *Patinopecten* of Japan, based upon *Pecten yessoensis* Jay, a common Recent scallop of Northern Japan.

Also, according to the writer's study (Masuda, 1971a), it became evident that among the species described from the West Coast of North America *Pecten* (*Patinopecten*) *bakeri* Hanna and Hertlein (1927), *Patinopecten bakeri diazi* Durham (1950a) and *Patinopecten marquerensis* Durham (1950a) described from the Pliocene strata of Baja California, Mexico, should be removed from *Patinopecten* and placed in the newly proposed genus *Leopecten* based upon *Pecten* (*Patinopecten*) *bakeri* Hanna and Hertlein. Moreover, it became evident that *Patinopecten* (*Mizuhopecten*) *skonunensis* MacNeil (1967) can not be referred to *Mizuhopecten;* but *Patinopecten* n. sp. illustrated by Addicott (1966) from the Montesano Formation in Washington was described by the writer as a new species of *Mizuhopecten* (Masuda, 1971a).

The typical *Patinopecten* is specifically abundant during the Tertiary Period in western North America but only one Recent species is known—*P. caurinus* (Gould) which occurs north of San Francisco Bay. *Patinopecten* has been usually considered as a cool water indicator of the West Coast of North America. MacNeil (1967) stated that most molluscan stocks on the West Coast of North America have older representatives in the Japanese Islands. However, as the writer pointed out (Masuda, 1963, 1971a), it is evident that the ancestral stock of *Patinopecten* is not a migrant from Asia but probably from the Mediterranean region.

In Japan the genus *Mizuhopecten,* ranging from the Oligocene to the Recent, is very abundant specifically and individually. But there are only two species known in the Pleistocene and only one from the Recent seas of Northern Japan. It seems probable that the majority of the *Patinopecten* species recorded from Sakhalin and Kamchatka should be referred to *Mizuhopecten,* and that *Patinopecten* may not be found in the western Pacific borderland.

In general, the water temperature gradually lowered from the early to latest Neogene in the Circum Pacific (Durham, 1950b, Masuda, 1963a, 1973b, Addicott, 1969), and the decrease in number of *Patinopecten* or *Mizuhopecten* species besides other pectinids during the Tertiary to the Recent may coincide with the lowering of the water temperature. It seems that the decrease in the pectinids on both sides of the Northern Pacific with advance of geological time may be explained by the changes of environmental conditions.

2) *Yabepecten*

Yabepecten established by the writer (Masuda, 1963) based upon *Pecten tokunagai* Yokoyama from the Pliocene Koshiba Formation in Kanagawa Prefecture, can be considered to be potentially significant in interregional correlation because of its restricted geological range and wide geographical distribution.

Masuda & Addicott (1970) pointed out that *Pecten (Amusium) condoni* Hertlein from the Montesano Formation of western Washington, is a *Yabepecten* and not an *Amusium.* This was the first record of *Yabepecten* in the Tertiary of eastern North Pacific. *Yabepecten* is restricted to early Pliocene formations of Northern Japan. Judging from the associated fauna, the early Pliocene formations of Northern Japan were deposited under cool water conditions. And, from the fauna associated with *Y. condoni* in the Montesano Formation, a probable early Pliocene age is suggested. Owing to its geological record and its wide geographical distribution, it is of considerable significance in Circum North Pacific faunal correlation. It is expected that *Yabepecten* will be found from Sakhalin, Kamchatka, Alaska and other areas along the Eastern Pacific.

3) *Swiftopecten* and *Nanaochlamys*

In 1935 Hertlein proposed *Swiftopecten* for *Pecten swiftii* Bernardi, a common Recent scallop of Northern Japan. Also *Nanaochlamys* was established by Hatai & Masuda (1953) based upon *Pecten notoensis* Yokoyama from the Miocene Nanao Formation, Ishikawa Prefecture, Japan.

As known at present the oldest occurrence of *Swiftopecten swiftii* (Bernardi) is the middle Miocene formations of Northern Japan, where it is rather rare (Masuda, 1959a). The associated molluscan fauna mainly comprises temperate water elements. But with the progress of geological age *S. swiftii* gradually increased its dominancy with the increase of cooler water mollusks from the middle Miocene through Pliocene to Recent (Masuda, 1959a, 1972).

As pointed out by the writer (Masuda, 1960), *Swiftopecten swiftii* branched off from *Nanaochlamys notoensis* (Yokoyama) in the middle Miocene. The morphological characters of *N. notoensis, N. notoensis otutumiensis* and *S. swiftii* closely resemble each other in their younger stage, but with growth the surface sculpture in the adult stage becomes considerably different. The surface sculpture in the younger stage of *N. notoensis* is retained in the adult stage of *N. otutumiensis* and *S. swiftii,* but the surface sculpture in adult stage of *N. notoensis* is not observed in that of the latter. And, *N. otutumiensis* and *S. swiftii* occur from a geological horizon higher than that of *N. notoensis.* Therefore, it is inferred that *N. notoensis* is ancestral to *N. otutumiensis* and *S. swiftii,* that is to say, *N. otutumiensis* and *S. swiftii* branched off from *N. notoensis* in the middle Miocene and they represent parallel forms of generic distinction. During the early Miocene *N. notoensis* was a warm water inhabitant as shown from the associated fauna. But it became extinct probably owing to the diverse environmental conditions at the end of the early Miocene. *Nanaochlamys otutumiensis* and *S. swiftii* branched off from *N. notoensis* in the late early Miocene. *Nanaochlamys otutumiensis* became extinct by the influence of rather cool water conditions of the late Miocene, but *S. swiftii* survived to the Recent with little morphological variations. Consequently, the factors controlling the evolutionary change in the *N. notoensis* group were probably due in part to the difference of environmental conditions. *Nanaochlamys notoensis* and *N. notoensis otutumiensis* are not known from Sakhalin, Kamchatka and Alaska.

The first appearance of *Swiftopecten* along the West Coast of North America is in the Yakataga Formation in Alaska, which yielded *S. donmilleri* (MacNeil, 1967; Kanno, 1971). It is thought that the occurrence of *Swiftopecten* along the West Coast of North America is a result of its migration from Asia to North America. Therefore, the writer considers that the Yakataga Formation in Alaska is at least not older than the middle Miocene formations in Japan. *Swiftopecten swiftii* extended its distribution to Northern California in the early Pliocene and *S. swiftii parmeleei* (Dall) which is known from Central to Southern

California, branched off from the *S. swiftii* stock as a result of its southward migration followed by localization and adaptation in the middle Pliocene and it became extinct at the end of middle Pliocene. On the other hand, with progress of geological age *S. swiftii* retreated to Alaska and became extinct in the Pleistocene. Therefore, it is expected that *S. swiftii* will be found from the Pliocene and Pleistocene formations of the northern part of western North America (MASUDA, 1972).

As already stated by the writer (MASUDA, 1959a), some morphological differences such as concentric constrictions or the nature of the radial ribs of the left valve in *Swiftopecten swiftii* are observed between specimens living in the northern areas and those living in more southern areas. These morphological features suggest that the specimens living in the northern areas are somewhat less influenced by the water temperature than those living in more southern areas. And, the morphological differences observed between the fossil and Recent specimens may be the reflection of the environmental conditions such as water temperature. From such inferences it may be interpreted that the so-called *S. kindlei* represents the northern type of *S. swiftii* and that some of the so-called *S. parmeleei* from northern California represent the southern type of *S. swiftii*. Also, the so-called *S. donmilleri* may represent the southern type of *S. swiftii*. Therefore, it can be considered that the Yakataga Formation that yielded *S. swiftii* may have been deposited under the influence of temperate to cool water environmental conditions. Although the geological age of the Yakataga Formation is now open to question, the writer is inclined to consider that a part of the Yakataga Formation may represent the late Miocene or very early Pliocene.

4) *Fortipecten*

Since YOKOYAMA (1930) described *Pecten takahashii* from the Pliocene Maruyama Formation in South Sakhalin, the species was frequently recorded from the Pliocene formations in Japanese Islands and Sakhalin. In 1940 YABE & HATAI established the genus *Fortipecten* based upon *P. takahashii* Yokoyama.

The genus *Fortipecten* has hitherto been considered to be an important Pliocene pectinid of Northern Japan, until KOTAKA & NODA (1967) described *F. kuroishiensis* from the middle Miocene Ogawara Formation, Aomori Prefecture, Northern Honshu, Japan. Among three species of *Fortipecten, F. takahashii, F. kenyoshiensis* and *F. kuroishiensis,* known from the Japanese Islands, *F. takahashii* is the most important species, particularly from the viewpoint of its restricted geological range and very wide geographical distribution from middle Northern Honshu northward to Hokkaido and Sakhalin and Kamchatka (MASUDA, 1962b).

On the other hand, several species such as *Fortipecten takahashii, F. pilutunensis, F. sachalinensis,* and *F. mironovi,* have been described from North Sakhalin and Kamchatka (KHOMENKO, 1931; SLODKEWITSCH, 1938; ILYNA, 1963; KRISHTOFOVICH, 1964). And *F. hallae* (Dall) (MACNEIL, 1943) and *F. mollerensis* MacNeil (1967) have been described from Alaska. Therefore, the occurrence of *Fortipecten* in the Circum North Pacific is a result of migration from the Japanese Islands. However, those mentioned species are in need of further study to clarify their taxonomic relations. For example, according to the present writer's study based upon the holotype and topotype of *F. mollerensis* MacNeil, it is evident that MacNeil's *mollerensis* is different from *Fortipecten* and should be referred to *Mizuhopecten*.

5) *Chlamys cosibensis* (Yokoyama)

Chlamys cosibensis was first described by YOKOYAMA (1911) from the Pliocene Koshiba Formation, Kanagawa Prefecture. Thenceforth, this species has been frequently recorded from the Miocene to Pliocene formations of Japan and its adjacent areas.

The first occurrence of *Chlamys cosibensis* (Yokoyama) is in the middle Miocene of Northern Japan and at that locality the associated molluscan fauna consists mainly of temperate water elements. The ancestral form of *C. cosibensis* (*s. s.*) is considered to be *C. cosibensis hanzawae* Masuda (1959b) which is known from the early Miocene formations of Japan, where it occurs in association with warm water mollusks. With the progress of geological age *C. cosibensis* (*s. s.*) increased its dominancy in association with an increase of cooler water mollusks from the middle Miocene to early Pliocene. *Chlamys cosibensis* (*s. s.*) has been frequently recorded from the early Pliocene formations of the Japan Sea borderland and the Kwanto region (MASUDA, 1962b). It has been recorded from North Sakhalin and Kamchatka (SLODKEWITSCH, 1938; ILYNA, 1963; KRISHTOFOVICH, 1964, 1969). Also, as pointed out by the writer (MASUDA, 1973a) MacNeil's *C.* (*Swiftopecten*) *leohertleini* from the Pliocene Tachilni Formation at the western end of the Alaska Peninsula (MACNEIL, 1970) is a synonym of *C. cosibensis* (*s. s.*). Moreover, MACNEIL (1973) illustrated *C.* (*Swiftopecten*) *donmilleri* MacNeil from the Unga Conglomerate Member of Bear Lake Formation, Alaska Peninsula, but according to the writer's study of the specimens preserved in the collections of the California Academy of Sciences, San Francisco and Re-

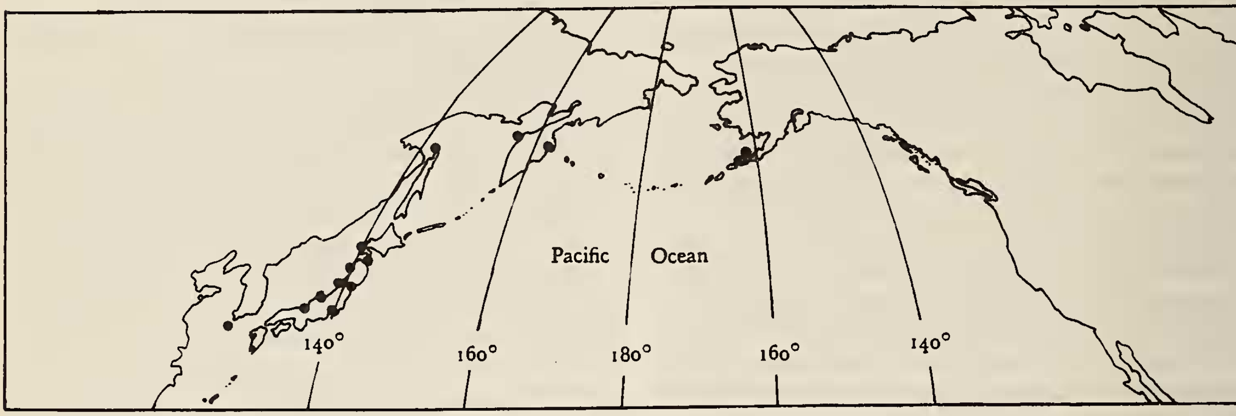

Figure 1

Geographical Distribution of *Chlamys cosibensis* (Yokoyama)

search Center of Amoco Production Company, Tulsa, from the same locality as MacNeil's *C. donmilleri*, it is evident that MacNeil's *C. donmilleri* is a synonym of *C. cosibensis* (*s. s.*), because the morphological characters are quite similar with those of *C. cosibensis* (*s. s.*). The geographical distribution of *C. cosibensis* (Yokoyama) is shown in Text figure 1.

The writer pointed out (MASUDA, 1973a) that the size of *Chlamys cosibensis* (*s. s.*) from middle Miocene formations is usually smaller than those from Pliocene formations and also that the radial ribs of the Miocene specimens are generally somewhat more distinct and somewhat higher than those of the Pliocene forms. Therefore, based upon morphological characters the geological age of the *C. cosibensis* (*s. s.*) bearing formations can be determined, and correlation of the geographically isolated formations can be undertaken. Since *C. cosibensis* (*s. s.*) from Alaska (MACNEIL, 1970, 1973; MASUDA, 1973a), Sakhalin (ILYNA, 1963) and Kamchatka (SLODKEWITSCH, 1938, KRISHTOFOVICH, 1969; MASUDA, 1973a) are of the Pliocene type of morphology, the writer considers that their occurrence is a result of migration from the Japanese Islands *via* Kamchatka to Alaska during the early Pliocene, although MACNEIL (1973) assigned the Unga Conglomerate Member of Bear Lake Formation in Alaska Peninsula to the early Middle Miocene.

6) *Amussiopecten*

Amussiopecten has been frequently recorded from various localities in Neogene and Paleogene formations in South and Central Europe, the Mediterranean Region, Iran, East Africa, Madagascar, South East Asia and East Asia, but no species has been described and recorded under *Amussiopecten* from either North America or South America. But according to the writer's study (MASUDA, 1971b) it became evident that several species from the Oligocene and Miocene formations along the West Coast of North America, Central America, the Caribbean Region and northern South America, should be referred to the genus *Amussiopecten*. And all species of *Amussiopecten* in Europe, Africa and America became extinct at the end of the middle Miocene, but three species of *Amussiopecten* in East Asia survived to the Pliocene.

In general, the decrease in number of species with time can be explained by the changes in oceanographic environmental conditions. Therefore, as the result of these changes all species of *Amussiopecten* in Europe, Africa and America became extinct at the end of middle Miocene but in East Asia three species were able to survive to the early Pliocene. That is to say, the environmental conditions in East Asia have been more stable than those of the other areas from the early Miocene to the early Pliocene. From the accounts given above it appears that the distribution of *Amussiopecten* has been dependent upon progressive changes in oceanographic conditions during its geological range. Therefore, world wide occurrences of *Amussiopecten* are considered to be very significant for interregional correlation.

The late Oligocene to Middle Miocene pectinids in North America are usually composed of European elements, but the Late Miocene to Pliocene pectinid fauna of the northern West Coast of North America generally contains a mixture of Asian elements, the survivors of Miocene pectinids and endemic genera. But along the southern West Coast of North America, the East Coast of North America and in the West Indies, the pectinid faunas differ greatly from those of the northern West Coast since the late Miocene. Along the southern West Coast the Pliocene pectinid fauna reveals a quite different aspect from those of northern part. These faunal provinces indicate geographic differentiation.

CONCLUDING REMARKS

The occurrences of the Japanese pectinids such as *Mizohopecten, Yabepecten, Swiftopecten, Fortipecten, Amussiopecten* and *Chlamys cosibensis* in the Neogene formations of the northern part of the West Coast of North America are significant for Circum Pacific correlation of the Neogene formations.

In general, there are two periods of remarkable development of the Pectinidae in the Tertiary of Japan (Masuda, 1962b). These two periods mark the abrupt appearance of genera and subgenera, extreme individual variability and species differentiation. The two unstable periods are represented by the early Miocene and early Pliocene ages (Masuda, 1962b; 1973b). Such remarkable features are also recognized in the Pectinidae of the "Vaqueros" and "Jacalitos" stages of the West Coast of North America (Arnold, 1906; Addicott, 1974), and also in the Japanese Turritellidae (Kotaka, 1959), Arcidae (Noda, 1966) and others.

The Miocene Pectinidae of Japan can be classified into early, middle and late Miocene (Masuda, 1962b). As stated earlier, during the early Miocene, the Pectinidae were abundant in species and individuals, showed a wide variety of sculpture and possessed a rather restricted chronological distribution. The early Miocene Pectinidae of Japan had a rather wide geographical distribution and was represented by the *Nanaochlamys notoensis* assemblage zone. In the middle Miocene the pectinid fauna became more varied, being represented in Northern Japan by the shallow water *Miyagipecten matsumoriensis* assemblage and the *Mizuhopecten kimurai* assemblage. In Southern Japan the pectinid fauna is represented by the *Amussiopecten akiyamae* assemblage, whereas in Central Japan there is a mixed pectinid assemblage consisting of the elements of Southern Japan and Northern Japan. Although the late Miocene pectinids are characterized by the mixed assemblage of the survivors of the earlier horizons and the appearance of some Pliocene species, their detailed characters are not well known, because of the restricted distribution of the pectinid-bearing formations.

Another development of the Pectinidae is recognized at the beginning of the Pliocene age in Japanese Islands. The early Pliocene is characterized by the *Yabepecten tokunagai* assemblage in the Japan Sea borderland and Kwanto region, the *Fortipecten takahashii* assemblage in the Northern Pacific borderland and the *Amussiopecten praesignis* assemblage in the Southern Pacific borderland. Among the early Pliocene pectinid assemblages, the *F. takahashii* assemblage can be traced from Northern Japan through Sakhalin to Kamchatka and the *Y. tokunagai* assemblage from Japan to the Alaska Peninsula. The *A. praesignis* assemblage can be traced from Central Japan to Taiwan and tends to change northwards gradually to the *Y. tokunagai* assemblage. The *Y. tokunagai* and *F. takahashii* assemblages may have been controlled within the same sedimentary province by ecological and other conditions.

Consequently, it is reasonable to correlate the early Pliocene formations of the Japanese Islands with the Pomyr Series in North Sakhalin, the Upper Kavran and Etronskaja Series in Kamchatka, the Tachilni Formation and Unga Conglomerate in Alaska, and also with the Montesano Formation in Washington. The mentioned correlation of the Pliocene formations in the Northern Pacific area is also supported by the other molluscan faunas.

ACKNOWLEDGMENTS

Acknowledgments are due to the late Dr. Kotara Hatai, Professor Emeritus of Tohoku University, Dr. A. Myra Keen, Professor Emeritus, Department of Geology, Stanford University, Dr. J. Wyatt Durham, Professor Emeritus, Museum of Paleontology, University of California in Berkeley, and Dr. David M. Hopkins, U. S. Geological Survey, Menlo Park, for their encouragement. The writer expresses his deep gratitude to Dr. Warren O. Addicott of the U. S. Geological Survey, Menlo Park, who helped him in various ways.

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